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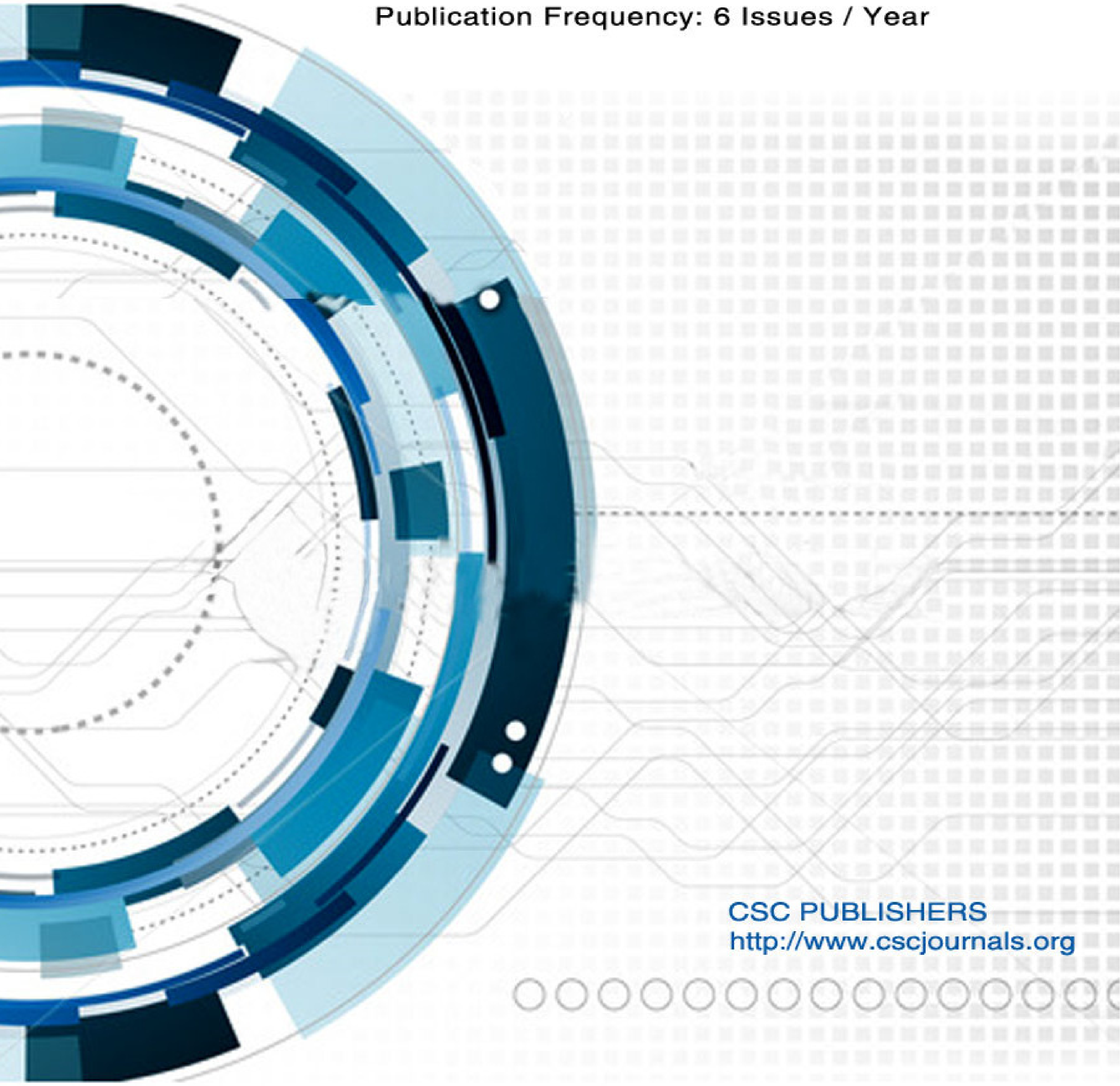

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EDITORIAL PREFACE

This is the *First* Issue of Volume *Nine* for International Journal of Engineering (IJE). The Journal is published bi-monthly, with papers being peer reviewed to high international standards. The International Journal of Engineering is not limited to a specific aspect of engineering but it is devoted to the publication of high quality papers on all division of engineering in general. IJE intends to disseminate knowledge in the various disciplines of the engineering field from theoretical, practical and analytical research to physical implications and theoretical or quantitative discussion intended for academic and industrial progress. In order to position IJE as one of the good journal on engineering sciences, a group of highly valuable scholars are serving on the editorial board. The International Editorial Board ensures that significant developments in engineering from around the world are reflected in the Journal. Some important topics covers by journal are nuclear engineering, mechanical engineering, computer engineering, electrical engineering, civil & structural engineering etc.

The initial efforts helped to shape the editorial policy and to sharpen the focus of the journal. Started with Volume 9, 2015, IJE appears with more focused issues. Besides normal publications, IJE intend to organized special issues on more focused topics. Each special issue will have a designated editor (editors) – either member of the editorial board or another recognized specialist in the respective field.

The coverage of the journal includes all new theoretical and experimental findings in the fields of engineering which enhance the knowledge of scientist, industrials, researchers and all those persons who are coupled with engineering field. IJE objective is to publish articles that are not only technically proficient but also contains information and ideas of fresh interest for International readership. IJE aims to handle submissions courteously and promptly. IJE objectives are to promote and extend the use of all methods in the principal disciplines of Engineering.

IJE editors understand that how much it is important for authors and researchers to have their work published with a minimum delay after submission of their papers. They also strongly believe that the direct communication between the editors and authors are important for the welfare, quality and wellbeing of the Journal and its readers. Therefore, all activities from paper submission to paper publication are controlled through electronic systems that include electronic submission, editorial panel and review system that ensures rapid decision with least delays in the publication processes.

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An Efficient Algorithm for Contact Angle Estimation in Molecular Dynamics Simulations

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Abstract

It is important to find contact angle for a liquid to understand its wetting properties, capillarity and surface interaction energy with a surface. The estimation of contact angle from Non Equilibrium Molecular Dynamics (NEMD), where we need to track the changes in contact angle over a period of time is challenging compared to the estimation from a single image from an experimental measurement. Often such molecular simulations involve finite number of molecules above some metallic or non-metallic substrates and coupled to a thermostat. The identification of profile of the droplet formed during this time will be difficult and computationally expensive to process as an image. In this paper a new algorithm is explained which can efficiently calculate time dependent contact angle from a NEMD simulation just by processing the molecular coordinates. The algorithm implements many simple yet accurate mathematical methods available, especially to remove the vapor molecules and noise data and thereby calculating the contact angle with more accuracy. To further demonstrate the capability of the algorithm a simulation study has been reported which compares the contact angle influence with different thermostats in the Molecular Dynamics (MD) simulation of water over platinum surface.

Keywords: Molecular Dynamics, Contact Angle, Algorithms, Mahalanobis Technique.

1. INTRODUCTION

It is quite common in the literature to use Berendsen or Nose-Hoover thermostat for liquid molecular dynamic simulations to study different thermodynamic properties of water. In this paper I have investigated the effect of such thermostats on the contact angle of water above platinum substrate.

In the past, Bo Shi et al [1] have simulated the contact angle of water on top of Platinum surface with FCC 111. Their work involved simulating columbic attraction with P3M method and keeping the temperature constant using Berendsen thermostat [2]. Maruyama and et al [3] have also done contact angle studies of water on platinum with truncated potential. Both researchers have used Zhu Philpott (ZP) potential [4] for water platinum interaction. There exists a wide range of literature on contact angle estimation for sessile drops over metallic and non-metallic substrates. However they are not mentioned here since the main focus of the paper is on contact angle estimation method for molecular simulations.

The paper is divided into two main sections, first explaining the MD simulation details and models used; second the new algorithm for contact angle estimation.

2. MD SIMULATION OF WATER ABOVE PLATINUM

A 6 nm3 water droplet (7221 molecules) is kept on top of FCC 111 platinum plate as shown in FIGURE 1. The slab geometry made of water in between platinum walls is applied with periodic boundary condition (PBC) laterally and wall boundary vertically. The platinum walls are of 20 nm^2 square and kept apart at a distance of 14 nm.

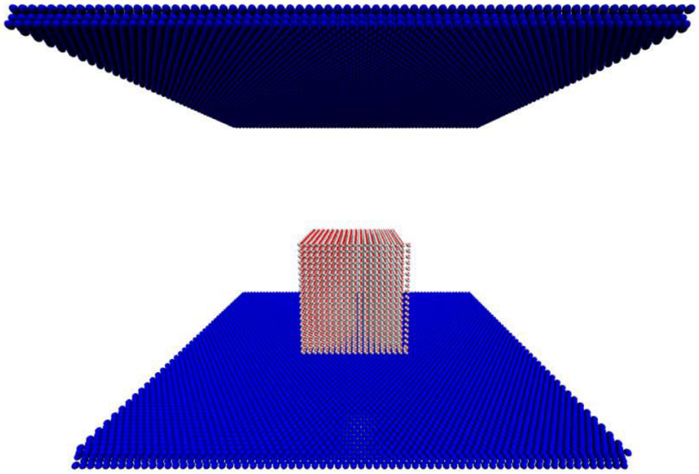

FIGURE 1: Simulation model for contact angle estimation.

The equations of motions are solved using Velocity Verlet [5] scheme. A shifted truncation scheme is used instead of Ewald summation methods or P3M. The feature of this scheme is that both potential and force goes smoothly to zero at the cut off radius.

$$U(r) = \frac{1}{4\pi\varepsilon_0}\left[\frac{1}{r} - \frac{5}{3r_c} + \frac{5r^3}{3r_c^4} - \frac{r^4}{r_c^5}\right] \tag{1}$$

The water molecules are modeled using Simple point charge extended (SPCE) model introduced by Berendsen et al [6]. The intra molecular bonds are kept rigid throughout the simulation using the SHAKE algorithm [7].

Since we are not modeling a contiguous array of droplets we can safely ignore the long range effects of the single water droplet. Simulation of droplet and films with SPME method will be studied extensively and will be published in another work.

Three cases of simulations with different thermostats are considered here. Berendsen [2], Nose-Hoover [8] and Velocity rescaling [9]. All the cases are run from 0ps to 1000ps using 2fs time integration steps. Gromacs [10] is the software package used for simulation.

At the end of simulation the trajectory files are processed and using the algorithm mentioned in the next section contact angles is determined. The time evolution of contact angle is shown in FIGURE 2. (a) and (b). The results indicate a transient behavior for contact angle.

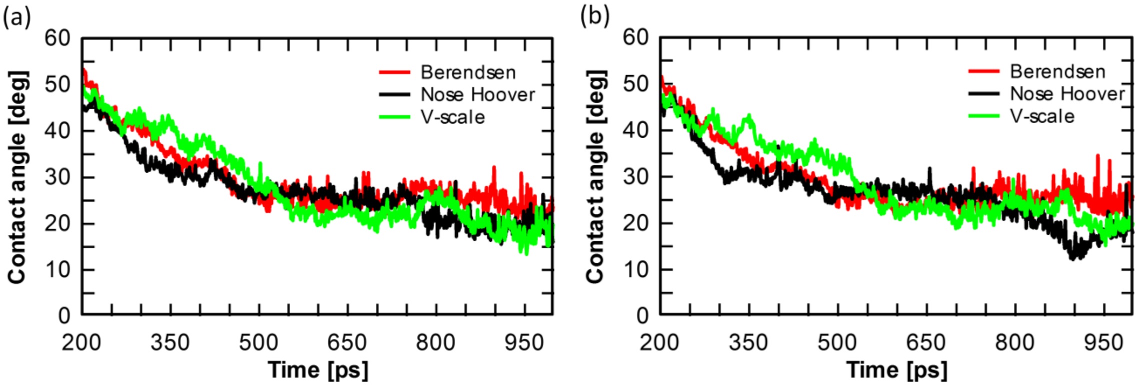

FIGURE 2: (a) Contact angle vs. time in XZ plane (b) Contact angle vs. time in YZ plane.

The contact angles seem to be fluctuating and never reaching a steady state. This is because of the nature of the potential function that we used for wall- water interaction (LJ potential). However this can be accounted by using ZP potential for water platinum interaction.

With the enormous amount of result data estimation of contact angle using visual or manual methods becomes a tedious process. There are not much algorithms which suit well for the direct post processing of molecular simulations. Hence the need for such algorithm raised and I have explained it in the next section.

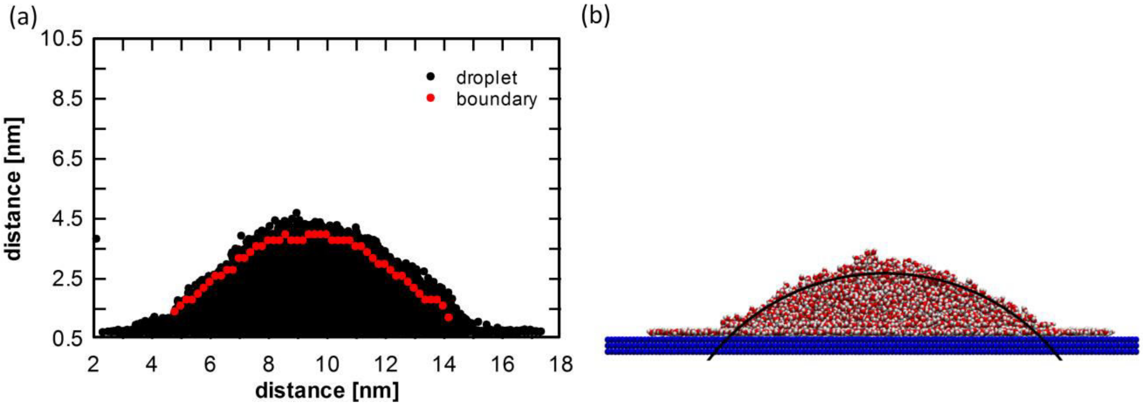

FIGURE 3: (a) Droplet particles (in black) and detected boundary (in red) (b) water molecules on top of platinum, black line shows the fitted circle from liquid vapor interface.

FIGURE 3. (a) shows a screenshot of molecular centroid after 300 ps simulation using case1 (Berendsen). The red dots show the location of liquid vapor interface detected using the new algorithm.

3. ALGORITHM DETAILS

Once obtaining the coordinate data (center of mass in case of water molecule) from the molecular simulations another challenge is to process the data to get a quality sample. Here a new method is explained to systematically find the boundary or edge of water droplet using simple mathematical methods and without using any image processing algorithms. For the convenience of the reader the whole process is divided into 5 steps.

We can process the data by projecting it normal to X-Z plane and also normal to Y-Z plane. (x, y) represents (X,Z) and (Y,Z) coordinates respectively for the data processing. FIGURE 4 shows screenshot of water above platinum surface after 500ps simulation.

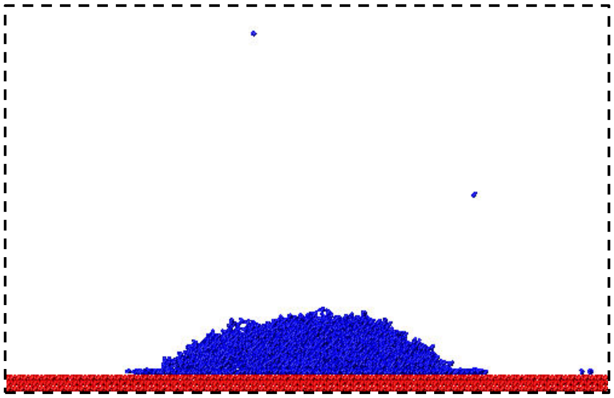

FIGURE 4: Water on top of Platinum [Berendsen 500ps].

3.1. Step 1: Preparing the Sample for Processing

The unwanted vapor molecules (outliers) in the data can be removed effectively using Mahalanobis Distance [11] technique.

If $X_c$is the $n \times 2$ column centered vector consisting of $(x-\bar{x}, y-\bar{y})$data of n points then variance-covariance matrix C_x is defined as:

$$C_x = \frac{1}{(n-1)}(X_c)^T(X_c) \tag{2}$$

Then the Mahalanobis Distance (MD) is calculated as:

$$MD_i = \sqrt{X_i C_x{}^{-1} X_i{}^T} \tag{3}$$

Where $X_i$is the mean centered data of ith data point. From this list of MD we can neglect those data points with considerably high MD values. For current study I have neglected all values above 4. Again this can be changed and fine-tuned according to the data.

The effectiveness of MD technique can be visualized from FIGURE 5. (a) and (b). The two vapor molecules which would have been a hindrance to estimate the contact angle accurately was removed easily with MD method.

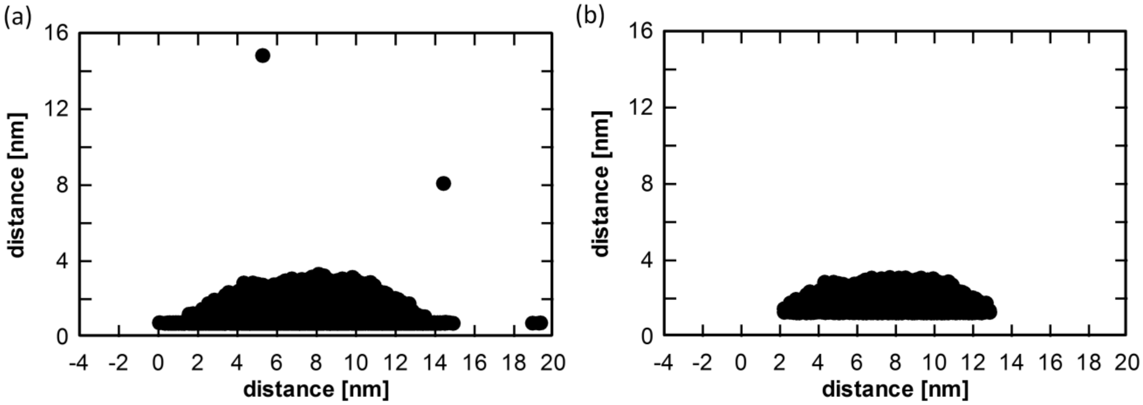

FIGURE 5: (a) Before removing the outliers (b) After removing the outliers and monolayer.

3.2. Step 2: Mesh based Contour Conversion using B-Splines

In this step a 2D mesh is generated and the entire droplet data is smeared into the grids using 4th order B-spline function. This makes it easier to find a smooth transition between the liquid core and the vacuum or vapor.

The Nearest Grid Point (NGP) method is a traditional first order method used to assign data to the grid points. Inspired from Hockney and Eastwood [12] the density of the molecules at every grid point can be calculated by the below equation.

$$\rho_{ij} = \sum_{p=1}^{N} W\left(\frac{|x_i - x_p|}{dx}\right) * W\left(\frac{|y_i - y_p|}{dy}\right) \tag{4}$$

Where the weight function is defined as

$$W(x) = \begin{cases} 1, & x < \frac{1}{2} \\ 0, & otherwise \end{cases} \tag{5}$$

The B-spline method is inspired from Smooth Particle Mesh Ewald [13]. Reproducing the definition gives, for any real number u, let $M_2(u)$ denote the linear hat function given by $M_2(u) = 1 - |u-1|$ for $0 \leq u \leq 2$ and $M_2(u) = 0$ for $u < 0$ or $u > 2$. For *n* greater than 2, define $M_n(u)$ by the recursion

$$M_n(u) = \frac{u}{n-1} M_{n-1}(u) + \frac{n-u}{n-1} M_{n-1}(u-1) \tag{6}$$

For our case *n* = 4 and *u* is in fractional coordinates.

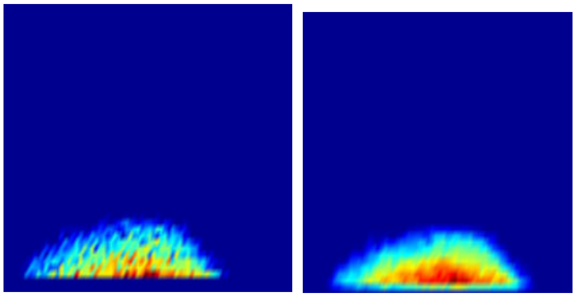

FIGURE 6: a) NGP assignment, b) B-spline assignment.

FIGURE 6. (a) and (b) shows the graphical representation of 2D density using NGP method and B-spline method. It can be seen easily that B-spline assignment scheme provides a smooth transition between liquid and vapor. Hence it is the recommended method for smearing.

3.3. Step 3: Filter Out the High and Low Density Data

As the next step towards the identification of the droplet boundary the grid points with high densities which resemble the liquid region and low densities that resemble the noise is eliminated based on the threshold densities defined as below.

$$Threshold_{MAX} = w1 * Mean \tag{7}$$

$$Threshold_{MIN} = w2 * Mean \tag{8}$$

$w1$ and $w2$ are weights which can be fine-tuned according to the data. For present analysis I have taken them as 2 and 0.5 respectively. Now all the data which meets the below criteria will be used for further analysis.

$$Threshold_{MIN} \leq Grid.value \leq Threshold_{MAX} \tag{9}$$

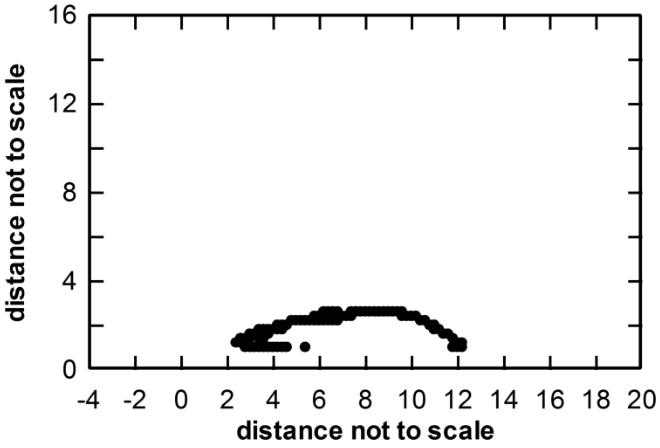

FIGURE 7: Filtered data (not to scale).

FIGURE 7 shows the data points obtained after applying the filter based on threshold density values. We can see that the interior liquid and exterior vapors have been eliminated.

3.4. Step 4: Finding the Ideal Location for Droplet Boundary

In this step we will find the centroid of the data obtained from the Step 3. If centroid lies below y-axis then set the y coordinate as the top of the platinum plate. This is to ensure that we prevent the erroneous semicircle shape which will lead to incorrect contact angle estimation. Then we radially move outwards from that point until we reach the boundary of data as shown in FIGURE 8. (a). This procedure is repeated for $0 \le \theta \le \pi$. If the centroid is above in the positive y-axis then the procedure is repeated for $0 \le \theta \le 2\pi$.

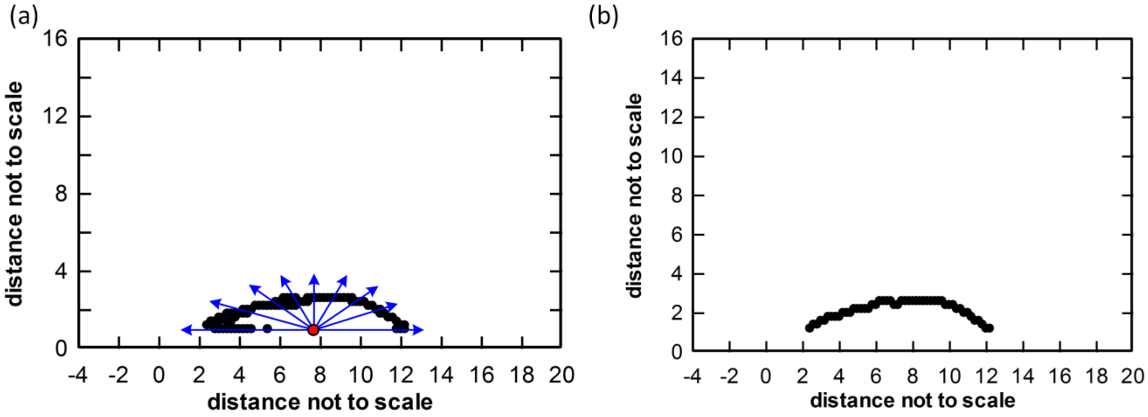

FIGURE 8: (a) Radial rays from centroid to find the extremities (b) Location of the droplet boundary.

At the end we will be left with a collection of points which forms the exterior of the droplet. FIGURE 8. (b) shows the final data points obtained using the algorithm.

3.5. Step 5: Finalizing the Droplet Boundary

These data points from step 4 are suitable candidates for final droplet boundary. Hence we fit them with Landau method [14] and find the circle which represents the droplet boundary. Once we get the equation of circle we can solve it for the angle made by the tangent at the platinum-water interface.

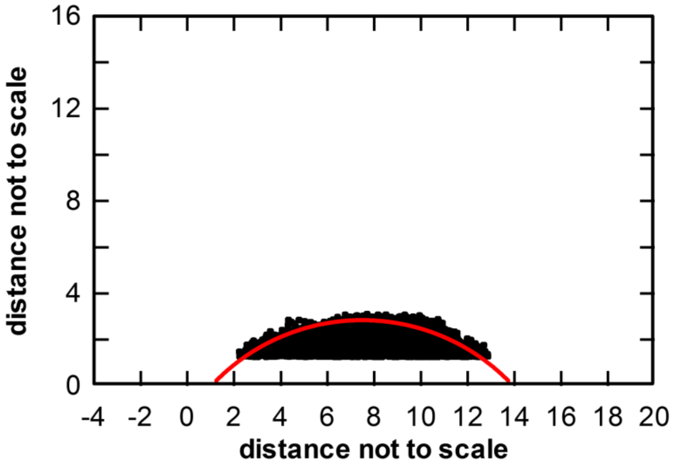

FIGURE 9: Final boundary of the droplet and fitted circle.

$$\theta = \tan^{-1}\left[\frac{(xc - x0)}{(yc - y0)}\right] \tag{10}$$

Where θ is the contact angle, (xc, yc) is the centroid of the fitted circle.

$$y0 = cutoff \tag{11}$$

$$x0 = xc - \sqrt{R^2 - (y0 - yc)^2} \tag{12}$$

Where cutoff is the distance above the platinum plate where we want to ignore the data points related to monolayer (high dense) region. R is the radius of the fitted circle. FIGURE 9 shows a typical droplet snapshot and also its detected boundary (in red) using the algorithm. The droplet is shown as single particles since their center of mass is only considered for analysis.

4. CONCLUSION

A new algorithm to accurately estimate the contact angle of the liquid from the molecular simulation results was presented in the paper. The algorithm is computationally efficient and accurate. Different parameters used in the identification procedure makes it easier to implement to new and different data sets. The different thermostat schemes and its effect on contact angle of water have also been discussed in this work. A MATLAB version of the algorithm will be provided upon request to author.

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] B. Shi, S. Sinha, and V. K. Dhir, in *ASME 2005 International Mechanical Engineering Congress and Exposition* (American Society of Mechanical Engineers, 2005), pp. 93.

[2] H. J. Berendsen, J. P. M. Postma, W. F. van Gunsteren, A. DiNola, and J. Haak, The Journal of chemical physics 81, 3684 (1984).

[3] T. Kimura and S. Maruyama, Heat Transfer 1, 537 (2002).

[4] S.-B. Zhu and M. R. Philpott, Interaction of water with metal surfaces, 1994.

[5] W. C. Swope, H. C. Andersen, P. H. Berens, and K. R. Wilson, The Journal of Chemical Physics 76, 637 (1982).

[6] H. Berendsen, J. Grigera, and T. Straatsma, Journal of Physical Chemistry 91, 6269 (1987).

[7] B. J. Leimkuhler and R. D. Skeel, Journal of Computational Physics 112, 117 (1994).

[8] W. G. Hoover, Physical Review A 31, 1695 (1985).

[9] G. Bussi, D. Donadio, and M. Parrinello, The Journal of chemical physics 126, 014101 (2007).

[10] B. Hess, C. Kutzner, D. Van Der Spoel, and E. Lindahl, Journal of chemical theory and computation 4, 435 (2008).

[11] R. De Maesschalck, D. Jouan-Rimbaud, and D. L. Massart, Chemometrics and intelligent laboratory systems 50, 1 (2000).

[12] R. W. Hockney and J. W. Eastwood, *Computer simulation using particles* (CRC Press, 2010).

[13] U. Essmann, L. Perera, M. L. Berkowitz, T. Darden, H. Lee, and L. G. Pedersen, The Journal of chemical physics 103, 8577 (1995).

[14] S. M. Thomas and Y. Chan, Computer Vision, Graphics, and Image Processing 45, 362 (1989).

Develop A Strategic Forecast of Silica Sand Based on Supply Chain Decomposition

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Abstract

As a commodity, silica sand is a low priced product but a primary ingredient for a diversity of products. On the whole, the consumption of silica sand can be measured as indicator to the global economy's trends and circumstances. The last decade showed a fluctuation in silica sand consumptions in several industries and reached the lowest level in 2009 due to the global recession. Due to the variety of products and the new or future developments in applications, the long term forecast of silica sand requires nonconventional methods of prediction. As an integrated part of the supply chain of numerous industries, silica sand demand has been decomposed into many sectors based on the intended applications. in this research. the impact of future demand of glass containers, flat glass, specialty glass, fiber glass, fracture sand, foundry sand, whole grain fillers, abrasive, gravel sand, recreation sand, chemicals, fillers, ceramic and filtration industries in the total global silica demand for the next decade. Each unique market position and its interconnection with other industries had been studied to draw a strategic long term forecast of silica sand based on market share of each industry.

Keywords: Silica Sand, Supply Chain, Forecast, Demand.

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1. SILICA SAND APPLICATIONS

In nature, silica raw material is occurring in extensive range of mineral and includes unconsolidated sand and consolidated rock. Impurities are very minor and commonly are clay minerals. The term silica sand is applied to quartz sand that conforms to the specifications of which the main composition, SiO_2 is greater than 99%, with very little contaminant oxide contents such as Al_2O_3, TiO_2, CaO, Fe_2O_3 and heavy minerals of less than 0.1% . The term glass sand means that silica sand with a specific size fraction ranges from (− 590) to (+ 105) micron [1]. Silica sand is most primary ingredient material in all glass industry. The purity of the silica sand determines color, clarity, strength and other physical prosperities of the glass products. The principle glass products using silica includes colorless and colored containers such as bottles and jars, flat glass for windows and automotive use, fiberglass, reinforcing glass fiber, light bulbs, fluorescent tubes, TV and computer screens. Its specialized applications include such products as piezoelectric crystals, optical products, and vitreous silica [2].

Besides ground silica, ceramic products such as tableware, wall or floor tile, and sanitary ware consist of metallic and non metallic material. Silica is a vital component in ceramic formulation process because it represents the skeletal structure where clay and flux are attached. The unique characteristics of silica will enhance the integrity, appearance, and thermal expansion that regulate heat transfer, drying and shrinkage [3] [4]. The low thermal expansion and resistivity to acidic attack nominate silica sand in building industrial furnaces comprehensively. In addition, industrial sand is the backbone component in a wide variety of building and construction products. Sand is laid on railroad tracks to provide traction for train engines in wet or slippery conditions. Favorably, silica sand enhances the flexural strength of the binding system without affecting the chemical properties. Ground silica adds durability to epoxy based compounds, sealants and caulks by improving the anti-corrosion and weathering properties [5] [6, p. 2013].

The purity and the grain size of silica improve the appearance, brightness, reflectance, color consistency, tint retention, resistance to dirt or yeast, cracking and weathering of architectural paint and coatings. Silica fillers decrease oil absorption and improve finish color. The durability of paints and coatings are strongly attached with the silica composition because it conveys excellent abrasion and corrosion resistance [7].

Silica sand been used in foundries to make molds into which molten metal is poured, creating a metal casting such as engine blocks. Silica's high fusion point of 1760°C and low rate of thermal expansion produce stable cores and moulds compatible with all pouring temperatures. The core sand can be thermally or mechanically recycled to produce new cores or moulds [8]. Moreover, Silica sand plays a critical role of a wide variety of metallurgical production. In metal production, silica sand acts as a flux to lower the melting point and viscosity of the slag to make them more reactive and efficient. Either alone or combination with lime, lump silica is required to achieve the desired base-acid ratio that required for purification. These base metals can be further advanced and tailored with other ingredients such as Carbone to achieve the desired properties of high strength, corrosion resistance or electrical conductivity. In addition, ferroalloys are essential to steel production, and industrial sand is used for de-oxidation and grain refinement [9].

To recover oil and gas, a well-rounded grain of fracturing sand, commonly known as proppant is drained down by high-pressure fluids pump into deep hole to sustain open rock fissures or create new fracture in reservoir rocks. To a certain degree, silica is chemically stable components and does not react or degrade when get in touch with acids or solvents. Therefore, Silica sand is used to remove contaminates volatile organics, bacteria, and residue from water supplies [10]. A uniform shapes and even grain size distributions of silica sand produce an efficient filtration process of drinking potable water from wells and or waste water.

Silicon-base chemical products such as silicon gels, sodium silicate, silicon alloys, silicon carbide, silicones, and soluble silicates employ silica as a primary raw material. The range of chemical product uses silica is extended to reach food processing, soap and cleaners industries. Also, silica is applied in the production of phosphoric acid for the fertilizer industry. Sandpaper, glass grinding, and stone sawing are using abrasive sand for cutting, material removal, and polishing processes [11]. Silica sand is a major player in sandblasting to remove paint, stain, and rust. Other applications of silica sand include agricultural and leisure applications [12]. Golf course and athletic fields use silica sand for sport and recreations activities. Also, silica sand is used in agricultural activities.

2. GLOBAL SILICA SAND MARKET

Several industries applied silica as a major component of production. In general, silica sand demand can be segmented into five major markets: glass, hydraulic fracturing, foundries, building products, and chemicals, as well as other smaller markets as given by figure (1) [13] [14]) [15]. The glass manufacturer and oil industries are the dominant silica sand customer. Together, they consumed around 58 % of the total silica production. With approximately 70 % of each glass batch being silica sand, float glass and glass container manufacturers are countable for the most use of silica sand. In 2011, Most of the production in the silica categories was destined for float glass making which accounting for 31 % of global silica sand consumption in volume terms. Meanwhile, the physical properties of fracture sand increases the flow rate of natural gas or oil and hence productivity. The silica hardness courtesy and high resistivity to corrosive environment enable it to deliver the required crush resistance of the high pressures present in wells. Therefore, the use of silica sand on oil industries had consumed 27 % for hydraulic fracturing and well-packing sand.

Foundry industries use silica sands in many casting applications. Sand consumption for casting application is around 14 % of the total silica produced worldwide. By providing a packing density, whole grain silica sand is put to use in flooring compounds, mortars, specialty cements, stucco, roofing shingles, skid resistant surfaces and asphalt mixtures. The %age of silica sand used for construction application, fillers and building products is count for 7 %. Whole-grain silica is assumed to devour 4 %; golf course sand consumed 3 %; and ground and ungrounded silica for chemical applications use 3 %. Other uses such as recreation and other applications sand accounted for the remaining 11 %.

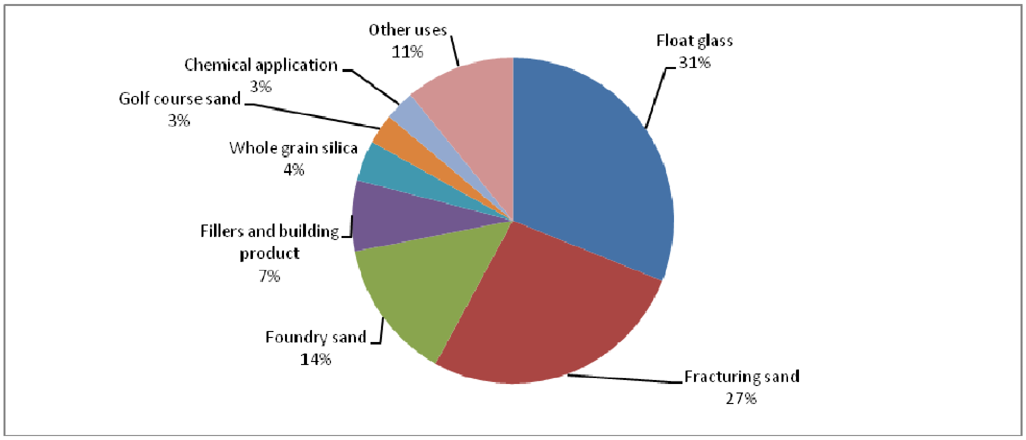

FIGURE 1: The diverse application of silica sand.

3. GLOBAL SILICA SAND PRODUCTION

The annual global production of silica sand is varying. In addition, the productions are differing between countries and continents as shown in figure (2) [15]. The total global silica sand production in year 2007 was approximately 122.0 million metric tons. Overall, production and consumption of industrial sand was down in 2009 due to the global recession that slowed economic activity beginning in 2008. The production of silica sand had been declined in the year 2008 and 2009 to reach 118.1 and 111.5 million tons, successively. Starting from year 2010, the global production of silica sand had been recovered and reached 118.2 million tons. This recovery of silica sand productions experienced a further improvement in year 2011 and year 2012. The silica global production reached 132.5 and 140.0 million tons in year 2011 and 2012, consecutively.

As a continent, Europe is the highest producer of silica sand. In 2011, Europe produced approximately 58 million metric tons of industrial sand. On average, Europe market share of silica sand production is approximately 47 %. The leading producers were Italy, Germany, United Kingdom, Austria, France, and Spain. The United States and Canada produced 43.7 million metric tons of industrial sand and gravel in 2011. The average %age contribution of North America to the total global silica sand production is estimated to be 28.5 %. Asia produced 9.8 % of the total silica production, while the contributions of Africa, Australia, and South America are marginal and account for 5.7, 4.5 and 4.4 %, respectively.

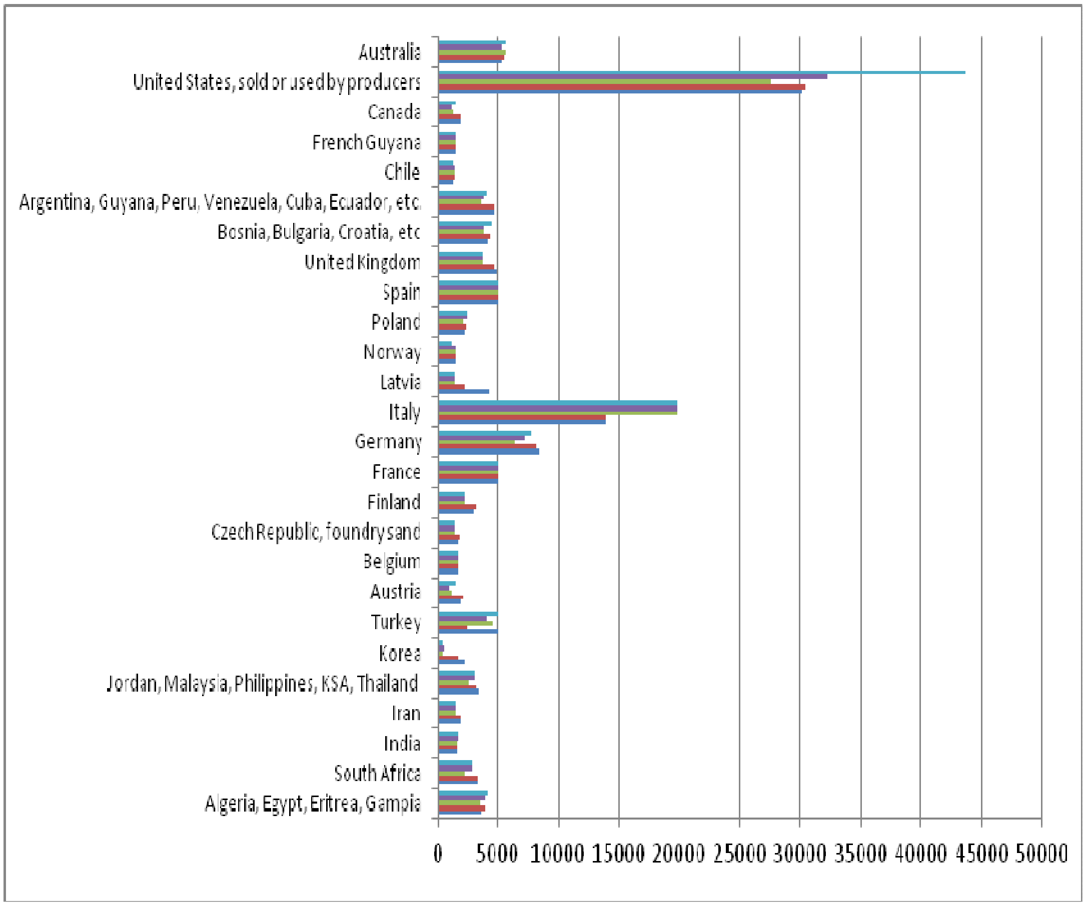

FIGURE 2: Global silica sand production for the year 2007 to 2011 in thousands tons.

4. USA PRODUCTION AND CONSUMPTION OF SILICA SAND

The consumption of silica sand in the United State for various activities is depicted in table (1) [15]. In 2011, the United State consumed 7.5 million tone of silica for glass manufacturing. On average and over the last decade, the United States consumed 9.4 million tone of silica for various glasses manufacturing applications which represents 30.5% of silica sand produced in the United State and approximately 7.8% of the global silica production. Petroleum industry consumed 24.9 million metric tons of hydraulic fracturing and well packing sand in 2011. Fracture sand represents 25.8% of the silica sand produced in the United States and 7.2% of the total global production. The U.S. foundry industries average consumption for the past decade was 4.7 million tons which represents 15% and 4% of the US and Global production, respectively. Other uses of silica sand in the United States include whole grain silica for building products, abrasive, ceramic, ground, pottery, brick, tile, etc. which counts for 28.6% of the total silica production in the United States and 7.3% of global silica production.

Sector	Year										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Containers	4610	4990	4560	4950	4970	4840	4585	4330	3950	3710	4202
Flat Glass	3550	3290	3410	3130	3370	3090	2880	2080	2530	2630	2979
Specialty	881	835	817	826	579	632	539	556	416	391	443
Fiberglass, un ground.	867	873	1040	1020	858	968	805	509	602	366	415

Fiberglass, ground	558	635	696	641	615	530	421	311	424	393	445
Foundry	5483	5258	5546	5464	5060	4354	4223	3174	3164	4739	5368
Abrasives	1270	796	784	908	453	498	579	430	469	512	580
Chemicals	877	867	771	830	816	812	826	669	808	707	801
Fillers, etc.	285	519	462	465	761	376	318	260	239	175	198
Whole grain	2100	2040	2460	2520	3160	2540	2240	1720	1820	1870	2118
Ceramic, etc.	323	221	192	208	221	185	137	88	91	106	120
Filtration	456	323	474	434	497	300	266	320	241	713	808
Fracturing	1579	2230	3445	4283	4652	6400	8171	6642	12283	24859	28158
Recreation	1089	1126	1127	1317	1001	1238	1042	1062	671	707	801
Traction,	157	162	137	161	80	109	118	73	72	71	80
Roofing	242	261	266	255	205	439	640	382	358	504	571
Gravel	1400	1200	1000	900	900	1000	1100	600	600	300	340
Other uses	1573	1874	2513	2288	3502	1689	1510	1394	1162	947	1073
USA total	27300	27500	29700	30600	31700	30000	30400	24600	29900	43700	49500
Global Production	113000	117000	113000	113000	118000	129,000	124,000	116000	124000	138000	140000
USA %	24.1	23.50	26.28	27.08	26.86	23.26	24.52	21.21	24.11	31.67	35.36

TABLE 1: Silica production and consumption in USA.

5. METHODOLOGY AND ASSUMPTION

Similar to most strategic forecast and due to the variety of products that silica sand represents or encountered, the prediction of silica sand demand requires nontraditional methods. Also, the future demand, supply, and trend of silica sand market will be affected by the new or future trends in silica applications. . As a major ingredient for a variety of products and an integrated part of the supply chain of numerous industries, silica sand has been decomposed into many sectors based on the intended applications. The key effect of each market had been studied disjointedly to conclude its contribution in the global silica sand demand. the silica sand market had been discompose to glass containers, flat glass, specialty glass, fiber glass, fracture sand, foundry sand, whole grain fillers, abrasive, and gravel sand, recreation sand, Chemicals, fillers, ceramic, filtration, and other application.

Despite the emerging of large economy players such as china, the U.S. economy seems to be the persistent locomotive of the world economy. The globalization and the intensive world trade make the global economy highly integrated. The growth or recession of the US economy cannot be decoupled from the rest of the world as shown in figure (3) [16] [17]. As an engine for world economy and a dominant player of silica sand market share based on the mentioned historical data, United State is both the world’s largest producer and largest consumer of silica sand. On average, The U.S consumed about 26% of the global production. A statistical data from U.S survey has been executed to create a long term silica sand forecast model in the United States. The United State market trend of silica sand demand will be investigated and revealed globally. The future trends of each industry will be examined solo and a model for silica demand will be developed for every individual application.

The silica sand demand had been declined due to the world economy crises in the past decade. The economy crises reached its peak on year 2008 through 2011. Therefore, those years has been considered to be a base for growth and recovery of silica sand market. The successor years to the financial crises shows that the global economy began to retain its healthy pace gradually and steadily. The historical demand of silica sand for the past ten years will have a great influence on the long term prediction. Hence, the previous market behavior of silica sand and the consumption records combined with new and future trends have been considered to create a long term strategic prediction model. Accordingly, the future silica demand consider the progressive growth of world economy gradually and regularly since the economy crises. Besides, the effect of silica sand consumption rate as part of the supply chain with emphasis on the maturity level of the consumption has been considered. The past consumption of silica sand does not assume the linearity of the silica sand demand and the future years. Instead, it considers the linearity between the silica sand demand and a function of future years. The least square method has been implemented to find the coefficient of the model at the minimum possible error as follow:

$$Demand = aX + b$$
$$X = f(t)$$

Where;
a, b are the model coefficient that need to be determine by least square
f(t) is a function of the specific time period.

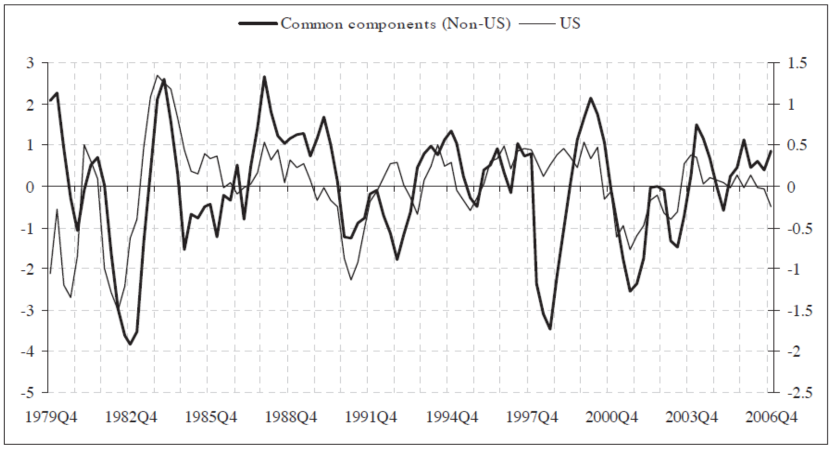

FIGURE 3: US real GDP growth rates and common component of rest of the world growth rates.

6. SILICA SAND SUPPLY CHAIN DECOMPOSITION

Silica sand is an essential part of the supply chain on container glass, flat glass, fiber glass, specialty glass, oil and gas recovery, metal casting, construction, and much other application. The future market demand of silica sand will depend on its application. Each silica sand market has opportunities, constrains, and trends.

6.1 Glass Container

Container glasses are chemically stable. Relatively, they are inert which give them the advantage to be used on wide range of products extensively. Also, they are transparent, do not deteriorate, corrode, stain or fade. The perceptions of glass containers as safer to use, sustainable and recyclable are among other advantages of glass containers. Contrary to petroleum-based products such as plastic, cans, and multi layered cartons, glass containers is soda-lime glass produced by blowing and pressing techniques. To preserve the taste of foods and beverages, glass containers are favorite choice and the most appropriate medium of packaging of beverages, pharmaceutical drugs and food items. Glass containers include glass bottles, jars, drink ware, bowls, pitchers, vases, and laboratory glassware.

The demand for container glass is almost stable over the past decade. Europe consumption of container glass was steady since 2006 at average amount of 21 million tone of container glass per year as shown in table (2) [18]. The demand for container glass in total EU 27 was 20.8

million tons in 2006 which is approximately the same demand in 2011. For year 2007 to year 2010 the demand was stable at 21.6, 21.3, 19.4, and 20.0 million tons, consecutively. Similar to Europe, U.S. features a stable demand for container glass as well. The silica demand for container glass does not vary significantly over the past several years. The demand for silica sand reached its peak of 5 million ton in year 2005. As consequences of the global economy recession experienced in 2008, the demand for silica sand had been decreased slightly in the successor years. In year 2012, the silica sand demand for glass container industries increase by 13% from previous year. Based on market stability of container glass over the past years, the expected demand on silica sand on the United State will show some steadiness and stability increase for the next decade as shown in figure (4).The demand for silica sand for glass container will expected to grow at 0.3% for the next following years to recover the pre-recession market demand.

Country	Year					
	2006	2007	2008	2009	2010	2011
France	3.83	3.74	3.58	3.15	3.15	3.31
Germany	3.89	4.08	4.14	3.78	3.79	4.07
Italy	3.55	3.62	3.67	3.33	3.51	3.57
Poland	1.12	1.23	0.87	0.91	0.99	0.99
Portugal	1.10	1.23	1.25	1.29	1.31	1.35
Spain	2.15	2.22	2.15	1.93	1.98	2.07
United Kingdom	2.16	2.24	2.43	2.12	2.32	2.31
EU North & Central	2.01	2.15	2.07	1.90	1.95	2.04
EU South-East	1.15	1.20	1.21	1.07	1.07	1.19
Turkey	0.60	0.71	0.77	0.61	0.78	0.82
Total Europe (EU27+CH+TR)	21.54	22.43	22.15	20.08	20.84	21.72
Total EU 27	20.87	21.62	21.27	19.37	19.96	20.79

TABLE 2: European container glass consumption in million tons.

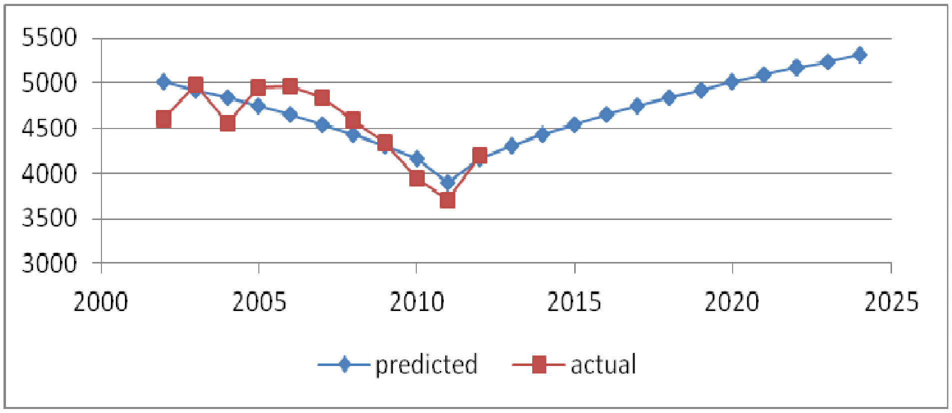

FIGURE 4: The forecasted demand of silica sand for glass container in USA in thousand tons.

6.2 Flat Glass

In general, The laboratory chemical composition of float glass batch is consisting of the following raw materials: silica sand, is the main component of the batch, as it constitutes about 51 % of the batch weight, soda ash, the flux, is one of the most expensive raw materials used in glass manufacturing and represents about 16 % of the batch weight and about 60% of the batch cost, Dolomite which is a carbonate mineral and it forms 13% of the batch weight, Limestone, a stabilizer, and represents approximately 4 % of the batch weight, and Sodium Sulphate counts for 1% of the batch weight [19]. In addition to those components, recycled glass known as cullet is added to the batch and form 15% of the batch weight. The chemical and physical specifications of the raw material are very causal factor in order to produce high quality flat glass. Silica sand in the form of SiO_2 is the dominant raw material and assumes up to 72% of the total float glass batch weight. It has a significant effect on the glass quality and hence, glass marketing

Beside window glass, the market of flat glass is extended to include automotive industry, Solar panels, and special application glass such as ultra thin glass for computers screens. Recently, the market value of fabricated glass such as basic flat glass as well as value-added products such as laminated, tempered, insulating and mirrored glass reaches high market value. Approximately, of the million tones of flat glass produced yearly, over 60 % is high quality float glass. The global market for float glass from year 2006 to 2011 was approximately 41, 50, 47, 52, 55, and 59 million tones, respectively. If we exclude year 2008 due the world recession, over the long term, demand for float glass is growing at almost 5 % per annum. This growth is fuelled by the demand for building glass and automotive glass, which in turn is driven by economic growth. China, Europe, and North America together are accounting for around three-quarters of global demand for flat glass. China accounts for 50% of the world glass demand. Europe consumed 16 % of global glass demand, while North America account for 8 % [14].

The demand on float glass is expected to increase by 5% annually. Hence, the demand on silica sand in flat glass industry is expected to grow up at the same level. In addition, the future market for architectural glass will benefit from the greater use of value-added glazing products, both in new structures and during major renovation and refurbishment activities. The trend to improve energy efficiency will make the double-glazed insulating glass units (IGUs) more popular. Introducing new generations of security and fire-rated glass, self-cleaning glass, and smart windows that promise unprecedented control and energy savings will also accelerated through near future [20]. In the United States, the demand for silica sand for float glass manufacturing reached the minimum level on 2009. Since then, the demand began to climb steadily at a rate of 4% as shown in figure (5). In year 2024, the US demand for silica sand is expected to reach 4.5 million metric tons.

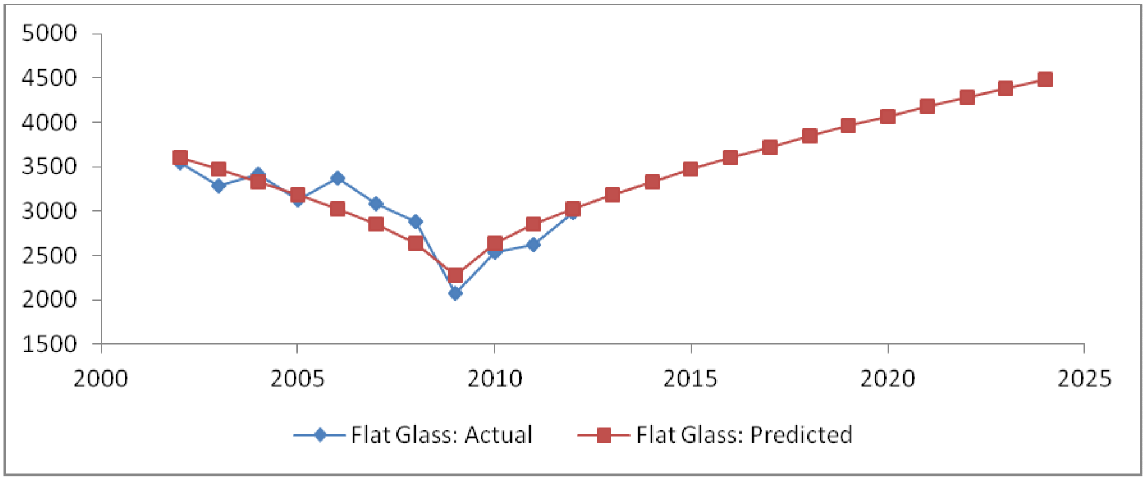

FIGURE 5: The forecasted demand of silica sand for float glass in USA in thousand tons.

6.3 Specially Glass

Primarily, specialty glass is a value-added flat glass produced by means of chemical and thermal processing of silica sand. The value added includes but not limited to laminating, tempering, and insulating process. The unusual characteristics of specialty glass indorse them for lenses industries. Optic fibers, mirrors, glassware and TV tubes are among other beneficiaries industries of the specialty glass purity. In addition specialty glass applied in security to prevent forced or burglary entry such as ballistic, blast resistance, abrasion, and impact resistance glass. The recent application of spatiality glass include fire or natural disaster resistance glass, and smart glass that has the ability to adjust according to weather or self cleaning glass, and noise control glass.

The over whole demand for silica sand had been decreased since 2002 in the United States as a consequences of the specialty glass market behavior. The consumption of silica sand for special glass was 881 thousand tons in 2002. Meanwhile, only 391 thousands tones were consumed in 2011. In 2012, most of public trade spatiality glass companies show an increase in revenue with median growth of 2.3% [21]. The recent increase has been driven by the new research and applications of specialty glass. The demands of ultra thin special glass for smart phone industries are increased significantly. The recovery of the motor vehicle industries, the new building construction, and the new legislation and standards promote the improvement of specificity glass market. Accordingly, the demand of silica sand for specialty glass applications will increase as shown in figure (6).

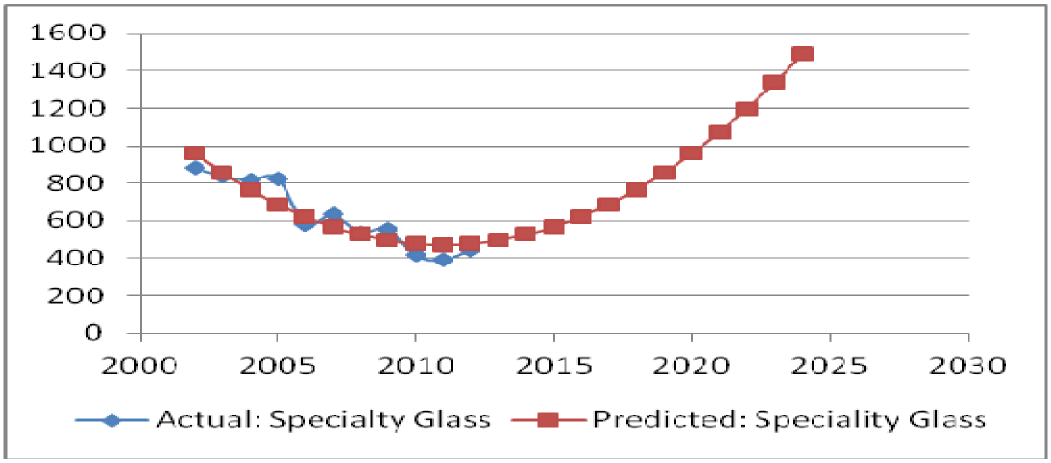

FIGURE 6: The forecasted demand of silica sand for specialty glass container in USA in thousand tons.

6.4 Fiber Glass

Fiber glasses are made of inexpensive raw materials such as silica sand, limestone, kaolin clay, fluorspar, colemanite, dolomite and other minerals. Manufacturing of fiber glass requires melting of these ingredients gradually to liquid form using large furnaces. The material then extruded and layered with a chemical solution. To provide roving, a large numbers of each individual filament is bundled collectively. These rovings are used in an intermediary step to manufacture fabrics. Eventfully, Fiber glass consists of plastic matrix such as epoxy or thermosetting plastic reinforced by fine fibers of glass is manufactured. The glass reinforcements are supplied in different physical forms, fine ground, chopped or woven.

The unique combination of light weight, extremely strength, less brittle, and none corroding give the fiberglass durability and robust chemical and physical characteristics. In addition, fiber glass is great insulator with low level of conductivity, low maintenance, and environmentally friendly. This uniqueness provides fiber glass a weather resistant finish with a variety of surface textures. Fiber glass finds its way through verity of applications such as aircraft, boats, sport tools, automobiles, tanks, baths, hot tubs, water tanks, roofing, pipes, cladding, casts, surfboards and external door skins. The strength and the light weight of fiber glass make it often used in safety equipments such as helmets. Also, fiber glass is used extensively in construction and house buildings such as roofing laminate, door surrounds, over-door canopies, window canopies and dormers, chimneys, coping systems, heads with keystones and sills.

With an exception of the holdback in the global economy in 2009, the demand of fiber glass has been increased over the past decade. China, USA, and Europe are the dominating manufacturer of fiber glass composite products. Fuelled with the increase applications of fiber glass especially in telecommunications and renewable energy products, the fiber glass are expected to grow up at 4.7% for the coming years [22]. Quality, technology, scale of operations, innovation, and price are among other factors that encourage the increase of fiber glass demand. Accordingly, the demand for grounded silica sand is increased from 393 million tons in 2011 to 445 million tons in 2012 as shown in figure (7). The ungrounded silica follows the same pattern as shown in figure (8).

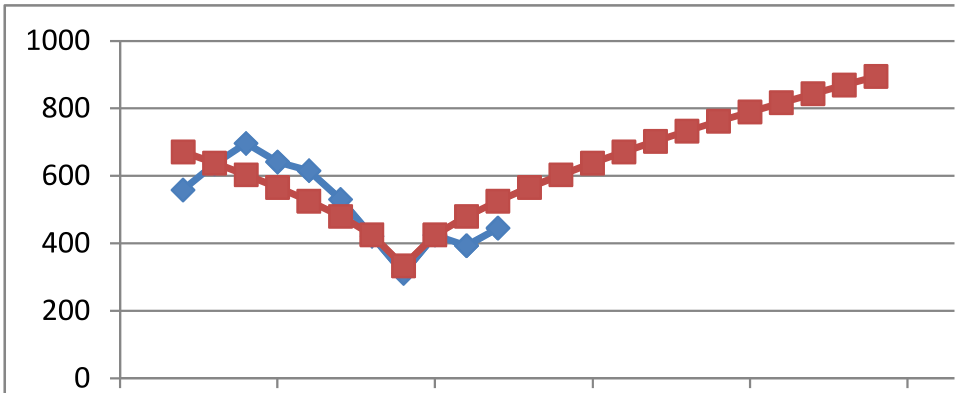

FIGURE 7: The forecasted demand of silica sand for ground fiber glass in USA in thousand tons.

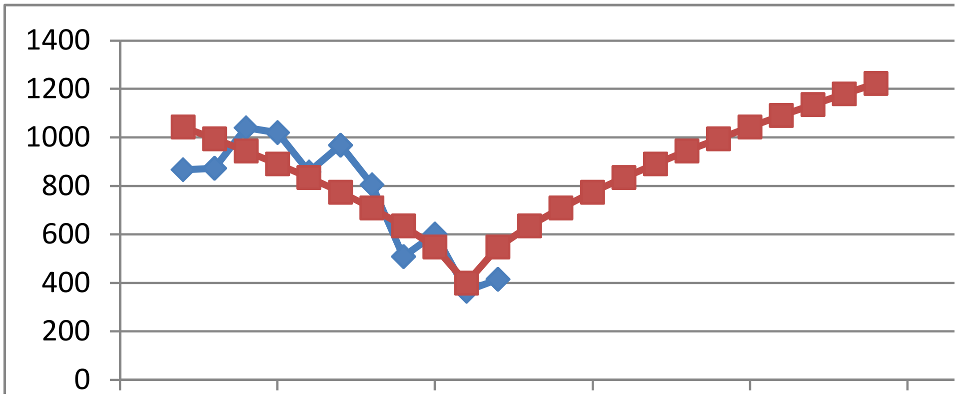

FIGURE 8: The forecasted demand of silica sand for un-ground fiber glass in USA in thousand tons.

.6.5 Fracture Sand

Proppants include natural fracture sand, resin coated sand (RCP), and ceramic proppant. The ceramic sand and RCP are having high quality and strength ability but they are expensive to produce. This makes natural fracture sand more favorable because it costs a fraction of ceramic and RCP. The frenziedly demand on energy sponsor upgrading and opening numerous of new mines. In return, the demand for fracture sand is boosting. The fracture sand is an essential material on exploring and gathering these nature resources and keeps them open to flow. Fracture sand includes high quality silica contents with a variety in particle size and shapes. It ranges from fine to course size sand. Also, it includes rounded spherical grains with high crush resistance and low fines content. In order to recover oil and gas, and due to its ability to withstand high pressure, fracture sand is used to propagate fracture through layers of low permeability rocks such as shale, or tight gas and unconventional liquids. Once the rock is fracture, fracture fluid consists of water, proppant, chemical additives, and guar gum are pumped to create network of interconnected fractures that enhance flow of oil and gas to well bore by keep the fractures propped open.

The main production and the largest consumption of hydraulic fracturing sand is North America. Most of the fracture sands are consumed by US and Canada. In the United States, the demand for natural fracture sand has been notably increased over the past several years. Today, the fracture sand is a major component in hydraulic fracture fluid used in most US oil and gas industry. Over the past decade, the production of fracture sand has been increased from 1.6 million tons in 2002 to approximately 24.9 million tons in 2011. Based on U.S. Geological Survey, Over the past ten years, the average production is 9.3 million metric tons, the average annual increase in production is 138% , and the average production of fracture sand represents 26% of the total US silica sand production and 7% of the global production. The average value for the average US production is $470 million dollar which represents approximately $46 per metric tons. In year 2011, the production of fracture sand was 24.8 million ton valued at 1.35 billion dollar ($54.4 per ton). The annual grow from previous year 2010 was increased by 202%. The US account for 18% of the total global production and 57% of the total US silica sand production [23]. The demand for fracture sand will not increase at the same rhythm. Rather, the increased demand for fracture sand will reach a maturity level in the united state. Based on the annual growth rate, the demand will be assumed to stabilize on the 40-50 million ton per year for the next ten year as shown in figure (9).

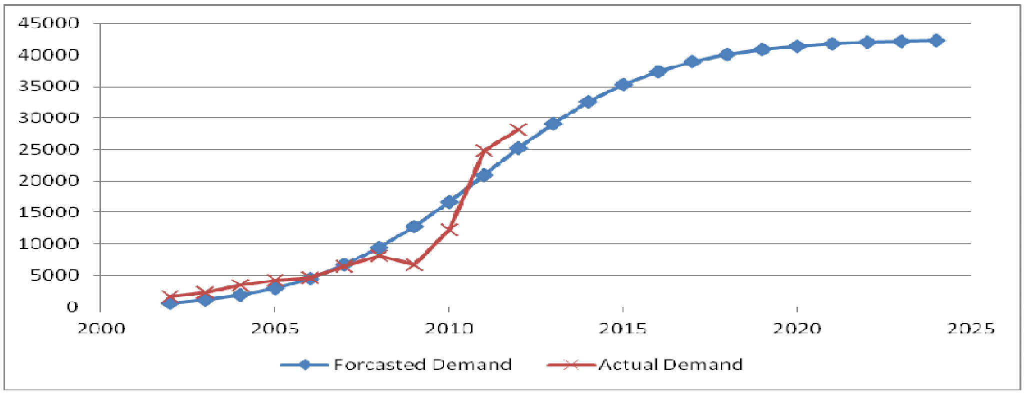

FIGURE 9: The forecasted demand of silica sand for Fracture Sand in USA in thousand tons.

6.6 Foundry Sand

Surface finish and dimensions are determining the quality of the cast. The availability, recyclability, high thermal resistance, and low thermal expansion are among other factors that make silica sand an essential raw material on casting processes. Silica ability to compact enables fabrication of high stable mold and cores, and hence quality cast. Primarily, foundry sand that bonded to form molds is consisting of uniformly sized silica sand, binder such as bentonite clay, 5% of water and about 5% of sea coal. Most ferrous material such as steel and non ferrous material such as cooper, aluminum and brass are manufacturing by sand casting to form the primary part shape prior to further machining process.

Metal parts ranging from engine blocks to sink faucets are cast in sand but the automotive industry and its parts are the major customer of foundry sand. Typically, about one ton of foundry sand is required for each ton of iron or steel casting produced [24]. The green sand used in the process constitutes upwards of 90 % of the molding materials used. The average annual consumption of foundry sand is 4.7 million metric tons for the past decade. Primarily, the silica sand consumption for foundry uses is connected to the automobile industry. The automobile industry starts to recover after the economic crises of 2009, and hence the silica sand. In USA, The demand for silica sand is expected to reach 5.5 million tones by 2012. Based on the growing trend of the foundry silica sand, the forecasted behavior of foundry sand can be represented as shown in figure (10).

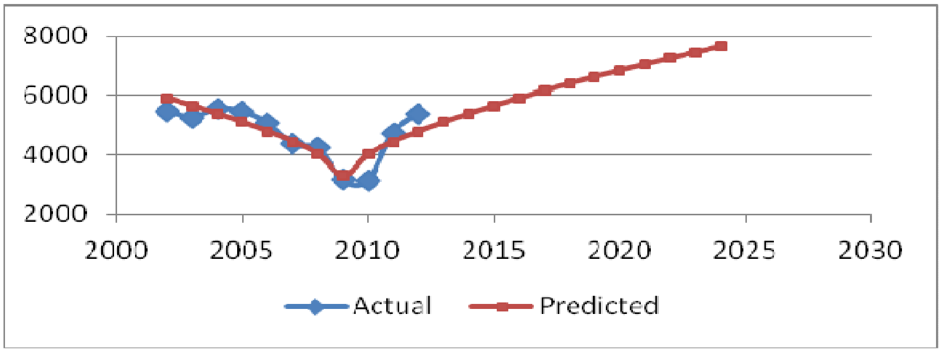

FIGURE 10: The forecasted demand of silica sand for foundry sand in USA in thousand tons.

6.7 Whole grain fillers and building products sands

To provide the necessary packing density and flexural strength, whole grain silica is used in asphalt mixtures. Whole grain silica has rounded, angular, and sub-angular grain shapes. Also, it has verities of size distributions to meet many application requirements. In construction and building products, industrial silica sand is a primary structural component. Silica does not altering the chemical prosperities of the binding system. Also it acquires the essential anti corrosion and whether resistance properties. Therefore, It had been used in flooring compounds, mortars, specialty cements, stucco, roofing shingles, and skid resistant surfaces.

In the past three years the demand for whole grain silica had been increased steadily. The construction of new road and building promote the demand for whole grain silica. the average demand for whole grain silica in the United State over the last decade was 2.2 million metric tons. The highest demand level was on 2006 of 3.1 million tons. In year 2008, the demands approached the minimum level due to the world economy catastrophe. Since then, the demands for silica sand for construction purposes begin to make progress. This increase in silica sand demand will be steady due to the limitation on bank mortgage and construction activities in general. The prediction of whole grain silica sand for the next decade can be formulated as shown in figure (11).

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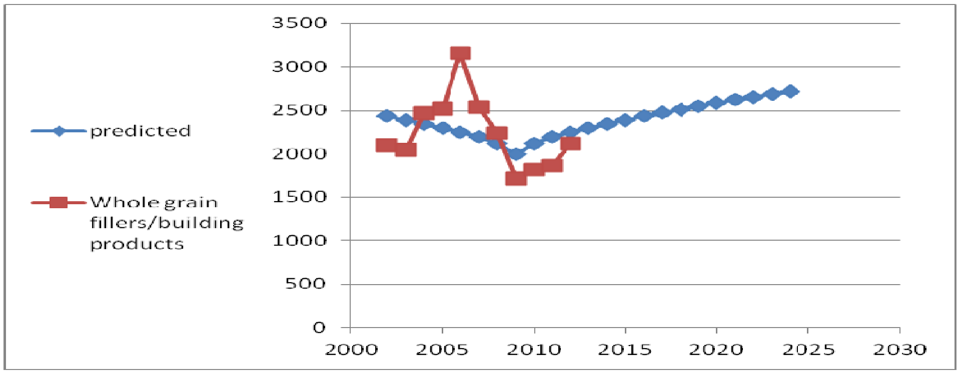

FIGURE 11: The forecasted demand of silica sand for whole grain silica in USA in thousand tons.

6.8 Abrasives

The difference in hardness between sand and the work piece encourages using the silica sand as an abrasive material. The ability of silica to penetrate and scratch other surfaces is an essential characteristic of any abrasive material. Silica sand in combined with other material has been used to shape or finish a work piece through rubbing or polishing. Natural or synthetic, Abrasives are extensively used in a wide variety of industrial, domestic, and technological applications.

Common uses for abrasives include grinding, polishing, buffing, honing, cutting, drilling, sharpening, lapping, and sandblasting.

The major market for abrasive sand is machining and construction industries. All metal part should be processed through machining, metal removal operation, and surface finishing. The abrasive sand market is directly connected to automobile industry and all metal fabrication industries. In the United State, the demand for abrasive sand had been declined on the past decade. The demand for abrasive sand was 1.3 million metric tons in 2002, while it declined to 0.5 million tons in 2011. The recent growth in automobile and metal part industries will be reflected on the abrasive silica sand demand for next decade as shown in figure (12).

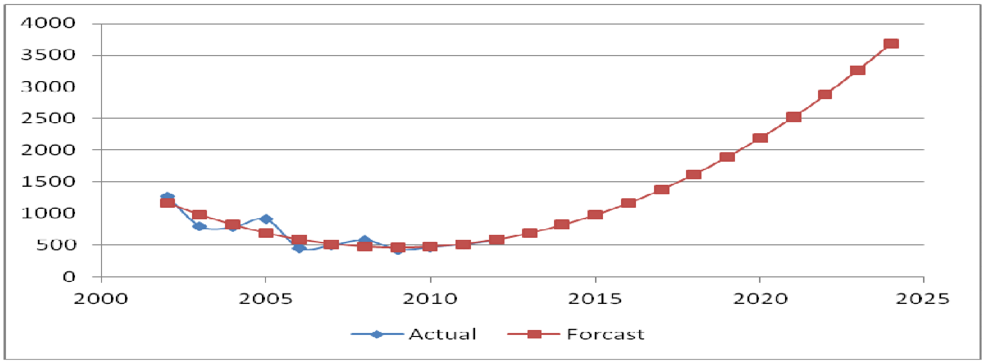

FIGURE 12: The forecasted demand of silica sand for abrasive silica sand in USA in thousand tons.

6.9 Gravel

Gravel is composed of unconsolidated rock fragments. Based on the particle size, gravel can be classified into granular gravel or pebble grave. Gravel is a heavy material and one cubic meter is about 1800 kilograms. Naturally, gravel is formed as a result of environmental erosion. It can pile up as sedimentary rock by the action of rivers or waves. Practically, the required size and specification of gravel is not available naturally in sufficient amount. The short in natural gravel supply can be accommodated through further mechanical processing such as crushing sandstone into smaller gravel pits.

Despite the last year improvement on gravel consumption in the United State, the demand for gravel had been dropped sharply during the past decade. The demand for gravel sand was 1.4 million metric tons in 2002 and dropped to 0.3 million metric tons in 2011. The demand for gravel rock will be recovered slowly as the need for building new road and maintaining the old ones as shown in figure (13). The improvement of constructions industries will have an influence on gravel demand as well. Based on the previous behavior and the future trend of gravel rock, the forecasted demand on gravel rock will be

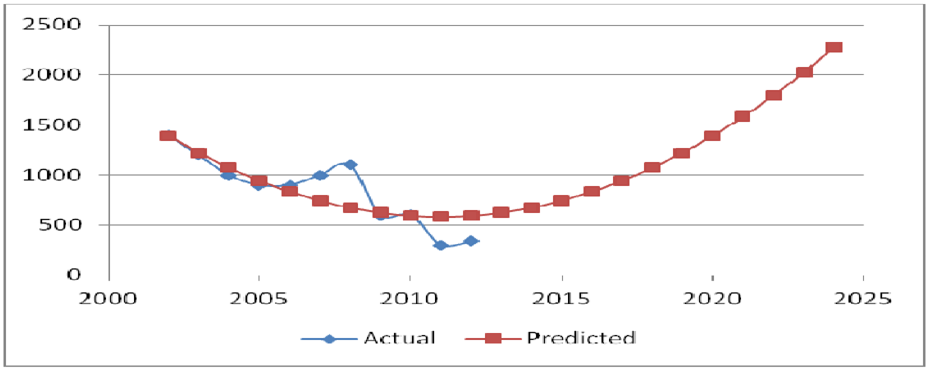

FIGURE 13: The forecasted demand of silica sand for gravel in USA in thousand tons.

6.10 Recreational Sand

Silica sand finds its way in recreation and sports applications. The stability of silica sand and the resistivity to contamination and growing media make silica sand suitable material for construction of athletic fields such as golf course, greens and traps, baseball, volleyball, play sand, and beaches. The natural grain shape, controlled particle size distribution, durability, and maintainability of silica provide the necessary permeability and compaction properties for drainage, healthy plant growth and stability.

Recreations activities tend to follow the general economic cycle. The past decade showed a decline in economy in most industrial sector locally and globally. Recreation is not an exception to that norm and the demand for silica sand for recreation activities have retain the increasingly trend in the past three years. Considering years 2010 through 2012 the demand has increase by around 16% annually The new predicted trend in silica sand for recreation activities will increase steadily as shown in figure (14).

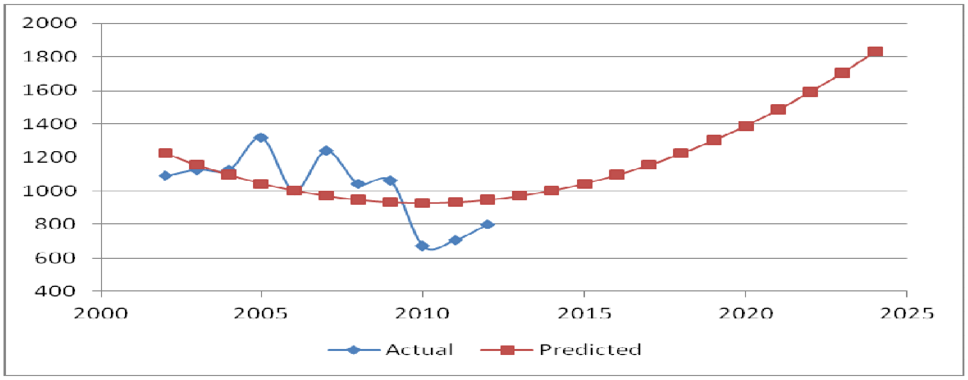

FIGURE 14: The forecasted demand of silica sand for recreational in USA in thousand tons.

6.11 Chemicals, Fillers, Ceramic, Filtration, and Other Application

Silica sand has numerous applications in diversity of product and industries. It is the essential raw metrical for many chemical products. Silicon based chemicals is essential material on daily product such as soap and food processing. In paint, metal, ceramic manufacturing industries, silica can be added to enhance the physical and chemical properties such as strength, hardness, appearance, and durability. Industrial sand is used in the filtration of drinking water and the processing of wastewater and many other daily life applications.

In the United State, the demand for silica sand for many applications from year 2002 to 2012 is shown in figure (15). The total demand for all other applications has been fluctuated between 3 and 5 million metric tons. Since the silica sand demand for those activities is small fractions of the total silica demand, it will be assumed that the demand for the next ten years will follow the same cycle of fluctuation around the average of 4 ± 2 million metric tons.

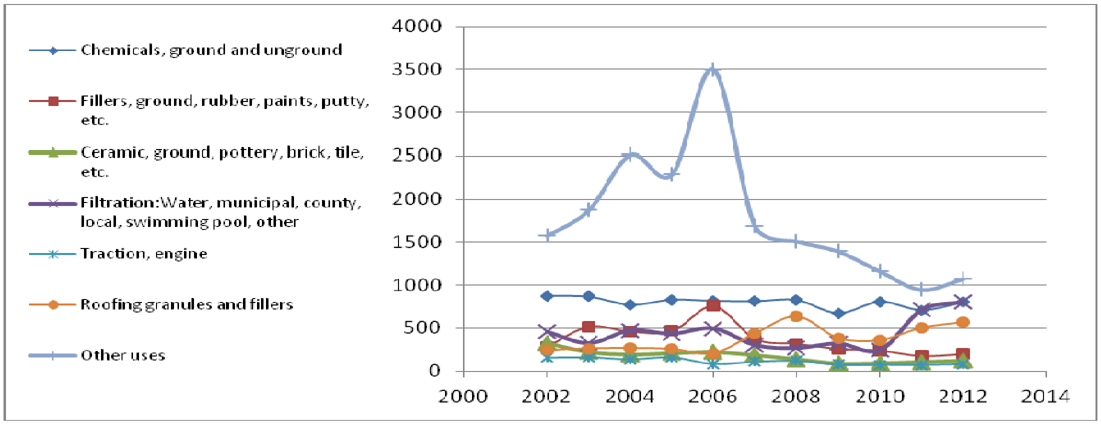

FIGURE 15: Other silica sand application in thousand tons.

7. SILICA SAND FORECAST MODEL

As a major manufacturer of silica sand, USA is considered as major player of the silica sand market and its application industries. Over the last decade, the average production of silica sand in the united state was 26% of the total global production. The last three years showed sharp increase in silica production in the United State. Considering years 2010, 2011, and 2012, US consumed 24%, 32%, and 36%, respectively of the total silica produced globally. Based on the decomposition of silica sand market supply chain, the sudden jump in the united state average share of silica sand is due to the increasing demand of fracture sand in oil industry. The uses of fracture sand in oil pumping begin to spread all over the world. Meanwhile, the use of fracture sand use will reach its maturity level in the recent future. Hence, the United State average global %age share of silica market will follow a linear steady trend. The United State market share of silica sand will oscillate between 30% and 36% for the next decade.

The future production of silica sand in the United State for each individual industry has been summarized in table (3). The total demand of silica sand will be the sum of all silica sand consumed from the supply chain industries. The proposed model which illustrated in figure (16) shows a great fit on the last ten years. The future trend for silica sand will be smooth and gradually increased. Silica sand production and consumption is based on the economic cycle of each individual application and the market trend for the next decade. The proposed model illustrates a significant association between US silica sand production and the global production. Both models experience the same experience and trends. In year 2015, the US production will reach 52 million tones and the global production will achieve approximately 200 million tons. The recovery from the recession will occur steadily on the next ten years. As a major component on the supply chain for many industries, the increasing trend of silica sand demand will promote the recovery and growth of world economy to retain its health manner in the recent future. By year 2025, these figures of silica production will experience a further steady increase to arrive at 58 million tons in US and 250 million tons globally.

According to a recent study from The Freedonia Group, the future construction spending, glass industry, foundry, and building products sectors are expected to drive growth in Silica Sand production and consumption. The global demand for industrial silica sand is forecasted to advance 5.5 percent per year to 291 million metric tons in 2018. Likewise, a research by iAbrasive forecasts the global demand for industrial silica is to increase 4.8 percent yearly through 2016. This research showed that the total production is expected to reach 280 million metric tons in 2016, with a value of $9.2 billion. Particularly, the rapid gains are projected for the hydraulic fracturing market as horizontal drilling for shale oil and gas resources expands. Nasdaq research predict an increase in Fract Sand per oil well and gas recovery markets. It estimates 300% increase in Fract Sand demand by year 2016. In addition, U.S. Silica's stock price is up 154% in the last 12 months.

Sector	*Coefficient*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*R*	*USA Demand Forecast Model*
Glass Container	3904.59	157.48	24.79	1.35E-09	3548.3	4260.8	0.83	$D = 255.6X + 3904.6$ $X = (t - 2011)^{3/2}$
	255.55	57.41	4.45	0.001	125.6	385.4		
Flat Glass	3904.59	157.48	24.79	1.35E-09	3548.3	4260.8	0.90	$D = 361.4X + 2280$ $X = (t - 2009)^{3/2}$
	255.55	57.41	4.45	0.0015	125.6	385.4		
Spacility glass	472.92	31.11	15.20	1E-07	402.5	543.3	0.92	$D = 6X + 473$ $X = (t - 2011)^{3}$
	5.98	0.83	7.18	5.15E-05	4.1	7.8		
Ground Fiber	332.97	49.23	6.76	8.24E-05	221.6	444.3	0.81	$D = 92.28X + 333.0$ $X = (t - 2009)^{3/2}$
	92.28	22.04	4.18	0.002	42.4	142.1		
Unground fiber	399.21	82.20	4.85	0.0009	213.2	585.1	0.86	$D = 14.92X + 399.2$ $X = (t - 2011)^{3/2}$
	148.92	29.96	4.96	0.0007	81.1	216.7		
Fracture sand	-601.06	1498.7	0.40	0.69	3991.3	2789.2	0.94	$D = 43123.0X - 601.1$ $X = \frac{1}{1 + e^{-0.4t+804.4}}$
	43122.71	5036.40	8.562194	1.28E-05	31729.5	54515.8		
Foundry Sand	3305.74	289.29	11.42	1.17E-06	2651.3	3960.1	0.88	$D = 712X + 3306$ $X = (t - 2009)^{3/2}$
	711.58	129.51	5.49	0.0003	418.6	1004.5		
Construction silica	2001.86	268.92	7.44	3.92E-05	1393.5	2610.2	0.31	$D = 118.1X + 2001.9$ $X = (t - 2009)^{3/2}$
	118.10	120.39	0.98	0.352	-154.2	390.4		
Abrasive silica	461.22	47.75	9.65	4.78E-06	353.18	569.2	0.90	$D = 14.3X + 461.2$ $X = (t - 2009)^{3}$
	14.32	2.29	6.24	0.0001	9.13	19.5		
Gravel	584.08	89.07	6.55	0.0001	382.5	785.5	0.81	$D = 10X + 584$ $X = (t - 2011)^{3}$
	10.19	2.38	4.27	0.002	4.7	15.5		
Recreation	928.80	78.07	11.89	8.29E-07	752.1	1105.4	0.5	$D = 4.6X + 929$ $X = (t - 2010)^{3}$
	4.61	2.76	1.67	0.12	1.6	10.8		
Chemicals, fillers, etc.								$D = 4\,million \pm 2$

TABLE 3: Forecast Result Model Summary.

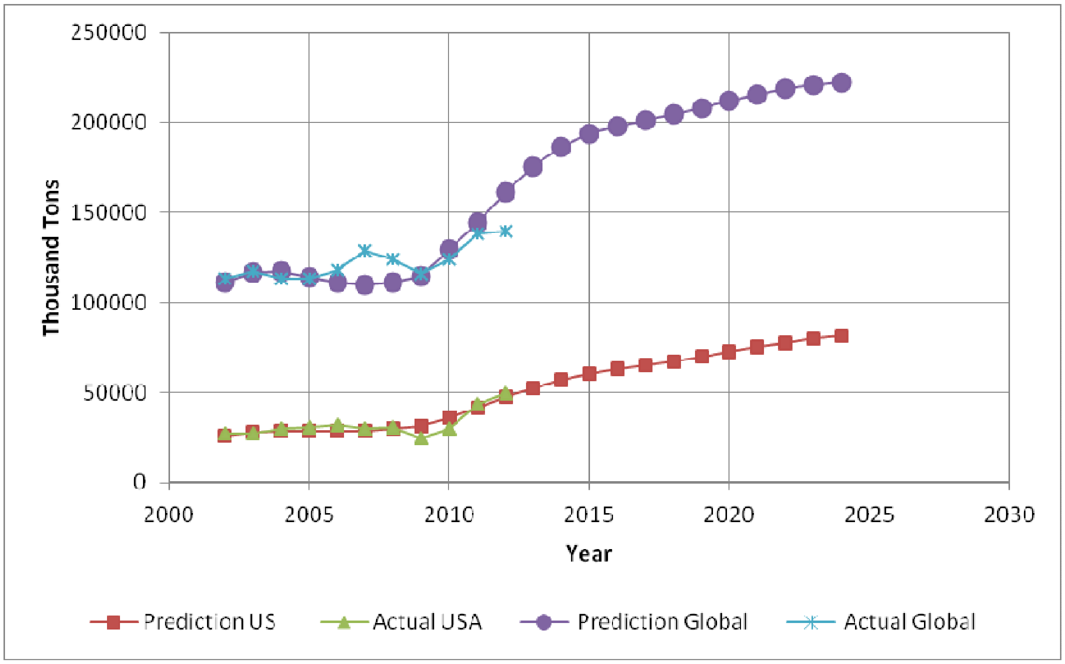

FIGURE 16: The USA and global silica sand strategic forecast model in thousand tons.

8. CONCLUSION

Over the next ten years, the demand on silica sand is expected to increase 5-6% annually. As a major component on the supply chain for a variety of industries, it is expected to experience an increase demand on products that silica sand form a major input. By decomposing the total silica sand demand into its root supply chain, a long term silica sand forest model has been formulated. Decomposing the silica market into major components gives the proposed forecast model the liability over dealing with silica sand production alone regardless the correlated industries. The strong association between silica sand and other industries that silica form a major element of the supply chain has support the strategic forecasted. The potential increase on silica sand demand is the summation of all factors that encountered with the silica sand application. As been realized from this research, silica sand is an essential raw material for production float or flat glass, container glass, fiber optics, fiber glass, gas and oil recovery, foundry, construction, and many other applications. This study demonstrates the future trend on each individual industry.

The relationship between silica production and the endless demand for energy will promote the silica sand production. The use of fracture sand in oil and gas recovery will be increased during the next decade. In addition, the future market for architectural glass will benefit from the greater use of value-added glazing products. The trend to improve energy efficiency will make the double-glazed insulating glass units (IGUs) more popular. Introducing new generations of security and fire-rated glass, self-cleaning glass, and smart windows that guarantee extraordinary energy savings will also accelerated through near future, and hence silica production. The economic recovery on metal and non metal parts manufacturing such as automobile industries will assure the increase use of foundry sand in casting process. The growth of construction sector will promote the demand in silica sand for buildings and roads structure. In addition, this study assures the integrated relationship between the U.S silica sand economy and the rest of the world. The production of silica sand will affect the integrated interconnected world economy. The effect of silica sand market in the U.S. has been deployed to predict the global demand for this material. As world largest customer for silica sand and by considering the future U.S market share, the global demand of silica sand is expected to reach 240 million metric tons by year 2024.

Furthermore, the emerging new technology on the next decade will increase the silica sand demand in both quality and quantity. Recent research assure that the use of silica sand in tire treads will reduce the rolling resistance and improve wet grip. Hence, silica sand will improve vehicle fuel economy and safety performance. The use of silica sand in tires industry will enlarge the future silica sand market. Accordingly, further research should be conducted on this low priced but a primary ingredient for diversity of products. An exhaustive analysis on each new emerging market on silica sand can be analyzed. The improvement of silica sand market display the global economy's trends, recovery and circumstances.

9. REFERENCES

[1] N. &. S. N. Kayal, "Stepwise complexometric determination of aluminium, titanium and iron concentrations in silica sand and allied materials," *Chemistry Central Journal,* 2007.

[2] "glass for Europe," [Online]. Available: http://www.glassforeurope.com/en/.

[3] A. K. Gupta, T. K. Dan, P. K. Rohatgi, "Aluminium alloy-silica sand composites: preparation and properties," *Journal of Materials Science,* pp. 3413-3419, 1986.

[4] Tomohiro Toyaa, Yoshikazu Kameshimaa, Atsuo Yasumorib, Kiyos, "Preparation and properties of glass-ceramics from wastes (Kira) of silica sand and kaolin clay refining," *Journal of the European Ceramic Society,* p. 2367–2372, 2004.

[5] Hui Zhao; Chi Sun Poon, Tung Chai Ling;, "Utilizing recycled cathode ray tube funnel glass sand as river sand replacement in the high-density concrete," *Journal of Cleaner Production,* p. 184–190, 2013.

[6] S.-C. Kou and C.-S. Poon, "A novel polymer concrete made with recycled glass aggregates, fly ash and metakaolin," *Construction and Building Materials,* pp. 146-151, 2013.

[7] B. g. s. (BGS), *mineral planning fact sheet, silica 2009,* national environment research council, 2009.

[8] E. I. S. H. R. Z. Moayed, "Stabilization of saline silty sand using lime and micro silica," *Journal of Central South University,* pp. pp 3006-3011, 2012.

[9] U. Nations, "UNU/IAS 2000. Section II: Industrial Sector Profiles," United Nations University/Institute of Advanced Studies, , 2000.

[10] Sheela G. Agrawal, Kevin W. King, Eric N. Fischer, Dedra N. Woner, "PO43− Removal by and Permeability of Industrial Byproducts and Minerals: Granulated Blast Furnace Slag,Cement Kiln Dust, Coconut Shell Activated Carbon, Silica Sand, and Zeolite," *Water, Air, & Soil Pollution,* pp. 91-101, 2011.

[11] D.-x. S. H. Z. M. W. L.-m. Z. Yan Zhu, "Improvement in properties of epoxy-based electrophoretic coating by silica/polyurethane nanocomposites;," *Journal of Materials Science,* pp. 545-550, 2007.

[12] A. G. A. Ergudenler, "Agglomeration of silica sand in a fluidized bed gasifier operating on wheat straw," *Biomass and Bioenergy,* p. 135–147, 1993.

[13] "Britsh Geological Survey," 2013. [Online]. Available: www.bgs.ac.uk/downloads/start.cfm?id=2930.

[14] N. group, "ANNUAL REPORT 2013," 31 march 2013. [Online]. Available: http://www.nsg.com/~/media/NSG/Site%20Content/Temporary%20Downloads/English/AR2013.ashx.

[15] M. C. S. T. P. D. U.S. Geological Survey, "SAND AND GRAVEL," January 2013. [Online]. Available: http://minerals.usgs.gov/minerals/pubs/mcs/2013/mcsapp2013.pdf.

[16] E. C. BANK, "annual report," 2009. [Online]. Available: www.ecb.europa.eu/pub/pdf/annrep/ar2009en.pdf.

[17] Vivek Arora and Athanasios Vamvakidis, "The Impact of U.S. Economic Growth on the Rest of the World: How Much Does It Matter?," *Journal of Economic Integration,* pp. 1-18, 2004.

[18] E. C. G. A. (CGA), "PACKED BOTTLES AND JARS," 2012. [Online]. Available: http://www.feve.org/images/stories/pdf2012/productionyr2012.pdf.

[19] K. W. K. E. N. F. D. N. W. Sheela G. Agrawal, "PO43– Removal by and Permeability of Industrial Byproducts and Minerals: Granulated Blast Furnace Slag, Cement Kiln Dust, Coconut Shell Activated Carbon, Silica Sand, and Zeolite," *Water, Air, & Soil Pollution,* pp. 91-101 ; S, 2011.

[20] A. L. A. H. J. H. Brouwers, "2010 Nano-silica production by a sustainable process; application in building materials," in *8th fib PhD Symposium in Kgs. Lyngby, Denmar*, Denmark, 2010.

[21] A. I. Park, "Specialty Glass Industry," Fall 2012. [Online]. Available: http://leaguepark.com/downloads/Specialty_Glass_Industry_Advisor_Fall_2012.pdf.

[22] G. F. C. Market, "Research and market Brochur," 2012. [Online]. Available: http://www.researchandmarkets.com/reports/2102021/ rt:.

[23] I. M. Silica and M. O'Driscol, "Frac Sand Frenzy Focus on supply & demand for hydraulic fracturing sand," 12-14 March 2012. [Online]. Available: http://www.indmin.com/.

[24] US department of transportation; Federal highway administration, "User Guidelines for Waste and Byproduct Materials in Pavement Construction," 97. [Online]. Available: http://www.fhwa.dot.gov/publications/research/infrastructure/structures/97148/fs1.cfm.

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